

The Genus *Isoëtes* L. in India

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The earliest reported Indian species, *I. coromandelina* was described by C. A. Linné, fil. in 1782 from the Coromandel coast, Tamil Nadu. For more than a century this remained the only species reported from India. Later workers found *I. coromandelina* in Karnataka, Kerala, West Bengal, Orissa, Bihar, Uttar Pradesh, Madhya Pradesh, and Gujarat. Mahabalé (1938) described a second species, *I. sahyadriensis* from a number of localities in the Western Ghats including Panchgani in Maharashtra and Kalahattigiri and Bababuddangiri and other peaks of Sahyadris in Karnataka. Soon thereafter, Rao (1944) and Shende (1945) described respectively, *I. sampathkumaranii* from Lalbagh Botanical Garden, Bangalore in Karnataka and *I. dixitei* from Panchgani in Maharashtra. These latter three reports of new species lacked detailed comparisons with previously described species. Subsequently, two more species, *I. panchananii* and *I. indica* were reported by Pant & Srivastava (1962). In their paper, Pant & Srivastava furnished detailed accounts and comparisons of their new species with all previously described Indian species. Recently five more species have been added to the list of Indian species. Two of these species were discovered in Madhya Pradesh. One species, *I. pantii* was described by Goswami & Arya (1970), and the other species *I. bilaspurensis* was described by Panigrahi (1981). The three remaining species *I. rajasthanensis*, *I. reticulata*, and *I. tuberculata* were described by Gena & Bharadwaja (1984). Two subspecies, *I. coromandelina* subsp. *coromandelina* and subsp. *brachyglossa*, were distinguished by Panigrahi (1981) on the basis of a reexamination of the herbarium specimens in the Kew Herbarium and British Museum (Natural History), London. A third subspecies, *I. coromandelina* subsp. *macrotuberculata*, was distinguished by Marsden (1976) from northern Australia. The eleven species from India is a relatively small number when compared to an estimated 400 to 500 species of *Isoëtes* world wide (personal communication Dr. H. P. Fuchs-Eckert). This low number of Indian species suggested a need for more extensive and intensive exploration for *Isoëtes* in various parts of India. For example no species of *Isoëtes* have been reported from the Himalayas, a region where *Isoëtes* should be found. Our recent explorations have yielded two species of *Isoëtes* which have not been previously described from peninsular India.

MATERIAL AND METHODS

Preliminary observations on fresh material were documented in the field. Living plants and specimens fixed in FAA were also studied in the laboratory at Allahabad. In the diagnoses and descriptions which follow the upper portion of the leaf is described as a limb and the flattened basal portion bearing the adaxial sporangium is described as a sheath. Spores were treated with HF, washed with water, and macerated with Schulze's fluid to separate different wall layers. Microspores were also acetolysed according to the method of Erdtman (1952). SEM photomicrographs were taken with a JEOL SEM model 35 C after sputter coating the dry untreated spores with a layer of gold-palladium approximately 200 Å thick. The descriptive terms used in the present paper follow the terminology of Jackson (1928), Kremp (1965), and Hickey (1986).

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NEW SPECIES

Isoëtes mahadevensis Srivastava, Pant & Shukla, sp. nov. (Figs. 1; 2, C, E; 3, A-D; 4, A-G; 6, C-D.). — TYPE: India, State of Madhya Pradesh, Distr. Hoshangabad, Pachmarhi, Chhote Mahadev; leg. G. K. Srivastava, no. 15011A, 1987, CAL; isotypes K, no. 15011B and Duthie hb. in Bot. Dept., Allahabad Univ. no. 15011C.

Planta subaquatilis; cormus bulbosus bilobatus vel nonnunquam trilobatus; et usque ad 15 mm latus; radices basi 0.2–1.2 mm crassae, folia 5–29, usque ad 14 cm longa, medio folio 1.0–1.5 mm lata, linearia, aliquantum extrorse incurvata, parallelimarginalia vel paululum undulata, parte distali in apicem longam subulatam fastigata, duae partes apicales folii stomatibus ornatae, vagina basalis applanata lutescente-subalbida usque ad 9 mm lata, unicum sporangium medianum adaxiale, (sive microsporangia in foliis exterioribus, sive megasporangia in foliis interioribus) portans, fibra fiberolignosa absentes; ligula trianguloidea, basi bilobata, 1.0–1.4 mm. lata et 0.9–1.3 mm longa, subfusca; labium triangulare, apice obtuso, albido-subflavidum, 0.43–0.65 mm latus et 0.30–0.5 mm longum; velum rudimentarium tholiforme, tegens sporangium 200 μ m circiter in parte superiore et 170–500 μ m ambobus lateribus solum; sporangia ovoidea, parte superiore applanata, 2–2.5 mm. lata et 3–4.5 mm longa; megasporae triletae obscure-griseae statu umescente, subalbidae statu sicco, dimorphae, i.e., duabus dimensionibus disparibus, maiores pyramidalis-globosae, 384 μ m–507 μ m (\bar{x} = 415 μ m), paries megasporarum quadritabulata, latere distali perisporii reticulato, lacunis completis vel interruptis, disjunctis inter se parietibus aut tam altis quam latis, aut latioribus altitudine selliformi, ornamentatione latere distali perspicue evoluta per costam aequatorialem, sed obscure aliis locis, latere proximali jugis triletis, rectus, tenuibus, 30 μ m–48 μ m altis, superficiebus pyramidalibus rugulis vel pustulis ornatis, costa aequatoriali undulata, tenue, usque ad 17 μ m alta; megasporae minores 203 μ m–372 μ m (\bar{x} = 297 μ m), paululum applanatae, ornameto ei megasporarum maiorum simili. sed facie distali indistincto, superficiebus pyramidalibus latere proximali pustulis distantibus, secundum micrographes microscopii electronici cibialis [i.e., Scanning Electron Microscope] superficie integra perisporii protecta fibris gelatinosis siliceis, interjectis, reticulum irregulare formantibus, saepe terminis singularibus solutis fractisque intra lacunas; exosporium atque mesosporium tenuiter granulata, firme conjuncta inter se, endosporium subtile, translucens, laevigatum, circumscriptione orbiculare; microspora generatim monoletae, rarius triletae, rotundae vel subrotundae, 10 μ m–47 μ m (\bar{x} = 33 μ m), costa proximali recta, tenui, membranacea, costa laesurali 10 μ m–30 μ m longa atque usque ad 9 μ m alta, pariete microsporii tritabulata, perisporio echinato secundum imagines microscopii luminaris [= LM] idem secundum micrographes microscopii electronici cibialis [= SEM], exosporio subtiliter pustuloso, mesosporio minute granuloso.

Plant submerged; corm bulbous usually bilobate, rarely trilobate and up to 15 mm wide; roots 0.2–1.2 mm thick at base; leaves 5 to 29, up to 14 cm long, 1.0 to 1.5 mm wide at midlength, linear, slightly bent, outwards, with parallel or undulating edges, tapering into a long attenuate apex, apical two thirds of leaf limb stomatiferous, flattened basal sheath up to 9 mm wide, yellowish-white, bearing a single median adaxial sporangium (microsporangium in outer and megasporangium in inner leaves), peripheral strands absent; ligule triangular, with lobed base, 1.0 mm–1.4 mm wide, 0.9 mm–1.3 mm long, brownish-yellow; labium triangular with obtuse apex, yellowish-white, 0.43 mm–0.65 mm wide and 0.30 mm–0.50 mm long; velum rudimentary, shaped like a dome, covering about 200 μ m of sporangial apex and 170 μ m–500 μ m of its two sides; sporangia ovoid, flattened at the upper side, 2–2.5 mm wide and 3–4.5 mm long; megaspores trilete, dark grey when wet, white in

dry condition, dimorphic, the larger ones pyramidal-globose, $384\ \mu\text{m}$ – $507\ \mu\text{m}$ ($\bar{x} = 415\ \mu\text{m}$), spore wall four layered, perispore retate distally, lacunae complete or broken, separated from one another by muri, thickness of muri (tangential width) almost equal to or greater their anticlinal height, ornamentation on distal face developed clearly along girdle, but obscure elsewhere, proximal face with straight, thin, trilete ridges 30 – $48\ \mu\text{m}$ high, inter-radial contact areas with small rugulae or pustules, equatorial ridge undulating, thin, up to $17\ \mu\text{m}$ high; smaller megaspores $203\ \mu\text{m}$ – $372\ \mu\text{m}$ ($\bar{x} = 297\ \mu\text{m}$), somewhat flattened, perispore ornamentation similar to larger megaspores, but indistinct on distal face, interrarial contact areas on proximal face with scattered pustules, in SEM photomicrographs the entire surface of perispore is covered by siliceous gel-fibres, interconnected with one another to form an irregular network, often with loose, broken ends within lacunae; exospore and mesospore finely granulate, firmly attached to each other, mesospore sometimes with numerous folds, edospore thin, translucent, smooth with circular, outline; microspores generally monolete, rarely trilete, round to roundly oval, $10\ \mu\text{m}$ – $47\ \mu\text{m}$ ($\bar{x} = 33\ \mu\text{m}$), proximal ridge straight, thin and membranous, $10\ \mu\text{m}$ – $30\ \mu\text{m}$ in length and up to $9\ \mu\text{m}$ high, spore wall three layered, perispore under LM and SEM echinate, exospore finely pustulate, and mesospore finely granular.

PARATYPE: India: State of Madhya Pradesh, Kasdol Distr. of Raipur: Kasdol Jungal, along water streams; leg G.K. Srivastava, No. 15021, 1987, Duthie hb. in Botany Dept., Allahabad Univ.

Plants of this species grow luxuriantly in small, shallow ditches either fully or partially submerged in water ($\text{pH} = 5.4$) and the soil is sandy and loamy. The siliceous gel-fibers mentioned in the diagnosis are formed by silica deposited in the form of a gel (Tryon & Tryon, 1982).

On the basis of megaspore ornamentation the retate (reticulate) megaspores of *I. mahadevensis* come closest to those of *I. panchananii*, *I. reticulata*, and *I. panchganiensis* whose megaspores are reticulate. The ornamentation of megaspores of *I. mahadevensis*, however, differs from that of the megaspores of the above mentioned species in having muri whose breadth and height are almost equal (the muri in other species are considerably higher than broad). The rugulate megaspores of *I. rajasthanensis* are also comparable with those of *I. mahadevensis*, but their muri too are higher than broad. In addition *I. rajasthanensis* differs from *I. mahadevensis* in having reportedly smooth microspores, whereas those of *I. mahadevensis* are echinate and unusually globose. The rudimentary velum of *I. mahadevensis* distinguishes it clearly from other Indian species belonging to the section *Terrestres* A. Br. [= *Reticulatae* Pfeiffer]. The velum in the other Indian species either covers nearly the entire sporangium or half of it as in *I. panchananii*.

The specific name "mahadevensis" chosen and derived from the type locality of the species "Chhote Mahadev."

Isoëtes panchganiensis Srivastava, Pant, and Shukla, sp. nov. (Figs. 2, A, B, D; 5, A-F; 6, A, B.). — TYPE: India, State of Maharashtra, Dist. Satara, Panchgani; leg. G. K. Srivastava, no. 15001A, 1987, CAL; isotypes: K. no. 15001B and Duthie hb. in Bot. Dept. Allahabad Univ. no. 15001C.

Planta subaquatilis; cormus trilobatus, diametro usque ad $12.0\ \text{mm}$; radices basi 0.2 – $0.9\ \text{mm}$ crassis; folia 9 – 20 , 7 – $13\ \text{cm}$ longa, medio folio 1.2 – $3.0\ \text{mm}$ lata, linearia, minute extrorse incurvata parallelimarginalia vel paululum undulata, parte distali in apicem longam spiculiformem fastigata, viridia duae partes folii, stomatibus ornatae, dilatata, vagina basalis applanata, lutescente-subalbida, usque ad $7\ \text{mm}$ lata, unicum sporangium medianum adaxialem portantia; ligula trianguloidea, basi lobii dilatata, $1.2\ \text{mm}$ – $2.1\ \text{mm}$ lata et 0.7 – $1.5\ \text{mm}$ longa, albido-flavida; labium triangulare, $0.5\ \text{mm}$ – $1.2\ \text{mm}$ latum et 0.5 – $0.7\ \text{mm}$ longum; velum hyalinum, sporangium fere omnino tegens, basi solum fenestram ovali-elongatum, $1.2\ \text{mm}$ latum et $0.8\ \text{mm}$ altum reliquens; sporangia ovoidea, parte superiore applanata, 2.5 – $3.0\ \text{mm}$ lata et 3.0 – $4.0\ \text{mm}$ longa; megasporae triletae, griseae



Fig. 1. Holotype of *Isoetes mahadevensis* No. 1501A. Bar = 1 cm.

statu umescente, albidae statu sicco, dimorphae, i.e., maiores pyramidali-globosae, $270\text{ }\mu\text{m}$ – $456\text{ }\mu\text{m}$ ($\bar{x} = 364\text{ }\mu\text{m}$), paries megasporarum quadritabulata, latere distali perisporii reticulato, lacunis generatim completis, disjunctis parietibus inter se, altitudine selliformi alteriore latitudine, costa aequatoriali sine reticulationibus, facie proximali jugis triletis, rectis, tenuibus, $35\text{ }\mu\text{m}$ – $50\text{ }\mu\text{m}$ altis, superficiebus pyramidalibus lacunis absentibus costa

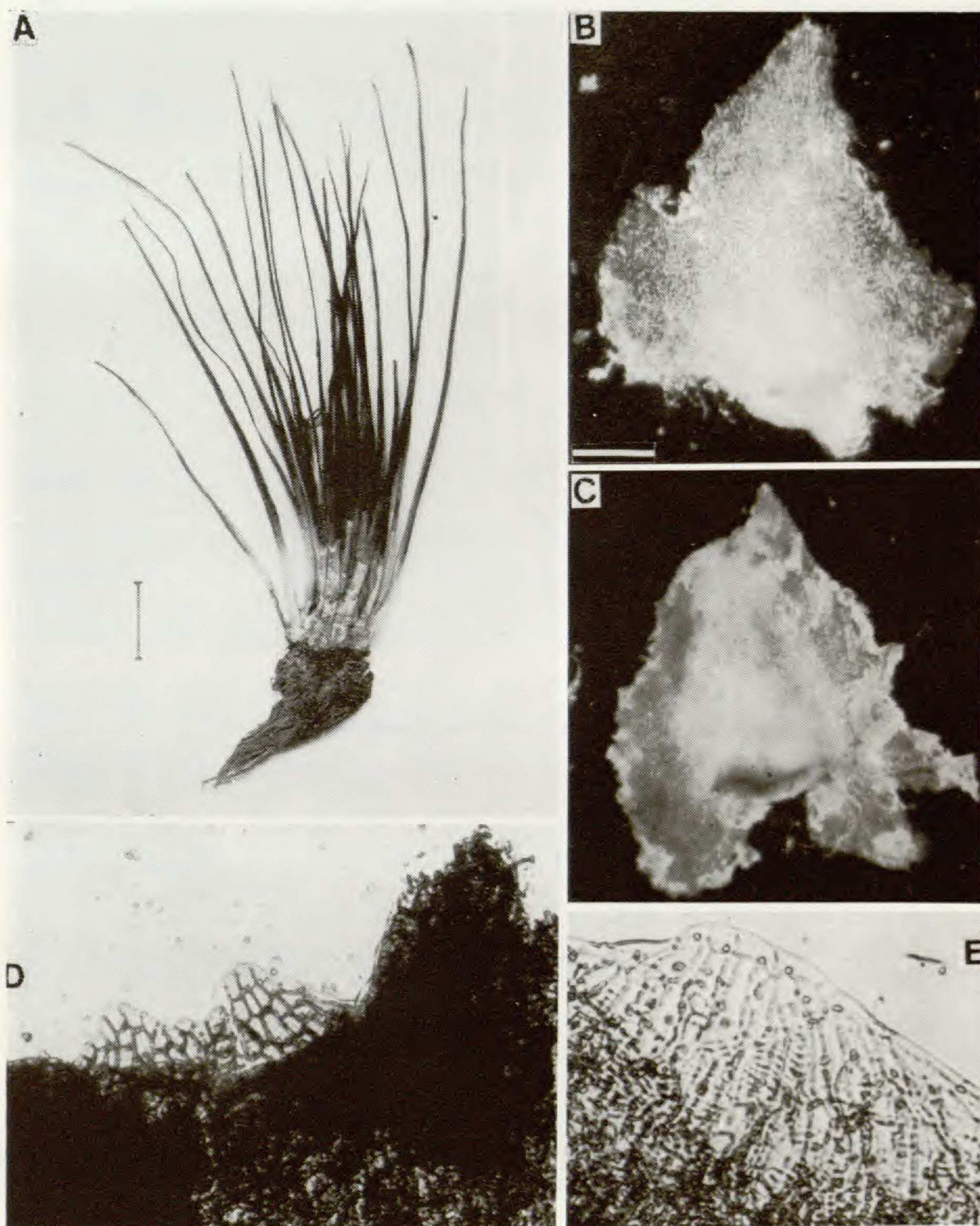


Fig. 2. A, B, D, *I. panchganiensis* and C, E, *I. mahadevensis*. A, Holotype no. 15001A; B, C, ligule of *I. panchganiensis* and *I. mahadevensis*; D, E, labium of *I. panchganiensis* and *I. mahadevensis* respectively. Bar in A = 1 cm; B, C = 185 μm ; D = 58 μm and E = 25 μm .

aequatoriali leviter undulata, 10 μm –17 μm alta; megasporae minores 185 μm –305 μm (\bar{x} = 244 μm), paululum applanatae, ornamento ei megasporarum majorum simili, sed facie distali indistincto, superficiebus pyramidalibus unico vel duabus pustulis, secundum micrographes microscopii electronici cibrialis [= SEM], superficie universa perisporii protecta fibris gelatinosis siliceis, nonnunquam interconnectis inter se, sed plerumque ter-

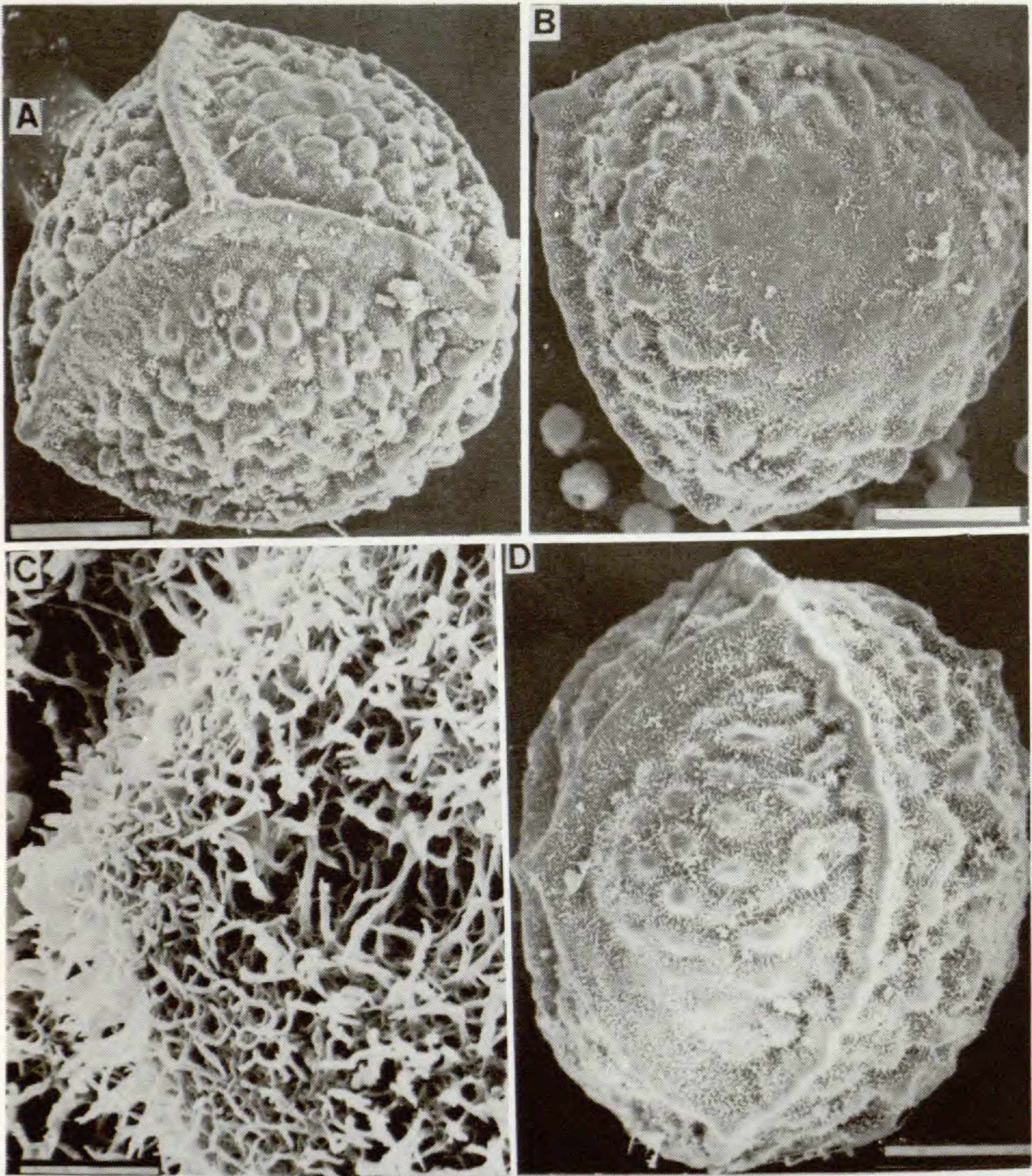


Fig. 3. A-D, SEM photomicrographs of megaspores of *I. mahadevensis*. A, proximal view; B, distal view; C, a portion of Fig. 3 B further magnified to show infrastructure details of the surface; D, lateral view. Bars in A, B, D = 100 μ m, and C = 10 μ m.

minis interruptis, formantibus imaginem irregularem retiformem in lacunis; exosporium et mesosporium tenuiter granulata, firme conjuncta inter se, mesosporium numerosis plicis superficialibus, endosporium subtile, translucens, laevigatum, circumscriptione orbiculare; microsporiae ignotae.

Plant submerged; corm bulbous trilobate up to 12.0 mm in diameter; roots 0.2 mm–0.9 mm thick at base; leaves 9–20, 7–13 cm long, 1.2 mm–3.0 mm wide at mid-length, linear, slightly bent, outwards, with parallel or slightly undulating edges, tapering into a long, attenuate apex, apical two thirds of leaf limb stomatiferous, limb green, flattened basal sheath up to 7 mm wide, yellowish-white, bearing a single median adaxial sporangium; ligule triangular, with expanded base, 1.2 mm–2.1 mm wide, and 0.7 mm–1.5 mm long yellowish-white; labium triangular, 0.5 mm–1.2 mm wide, 0.5 mm–0.7 mm long; velum hyaline, covering nearly the entire sporangium

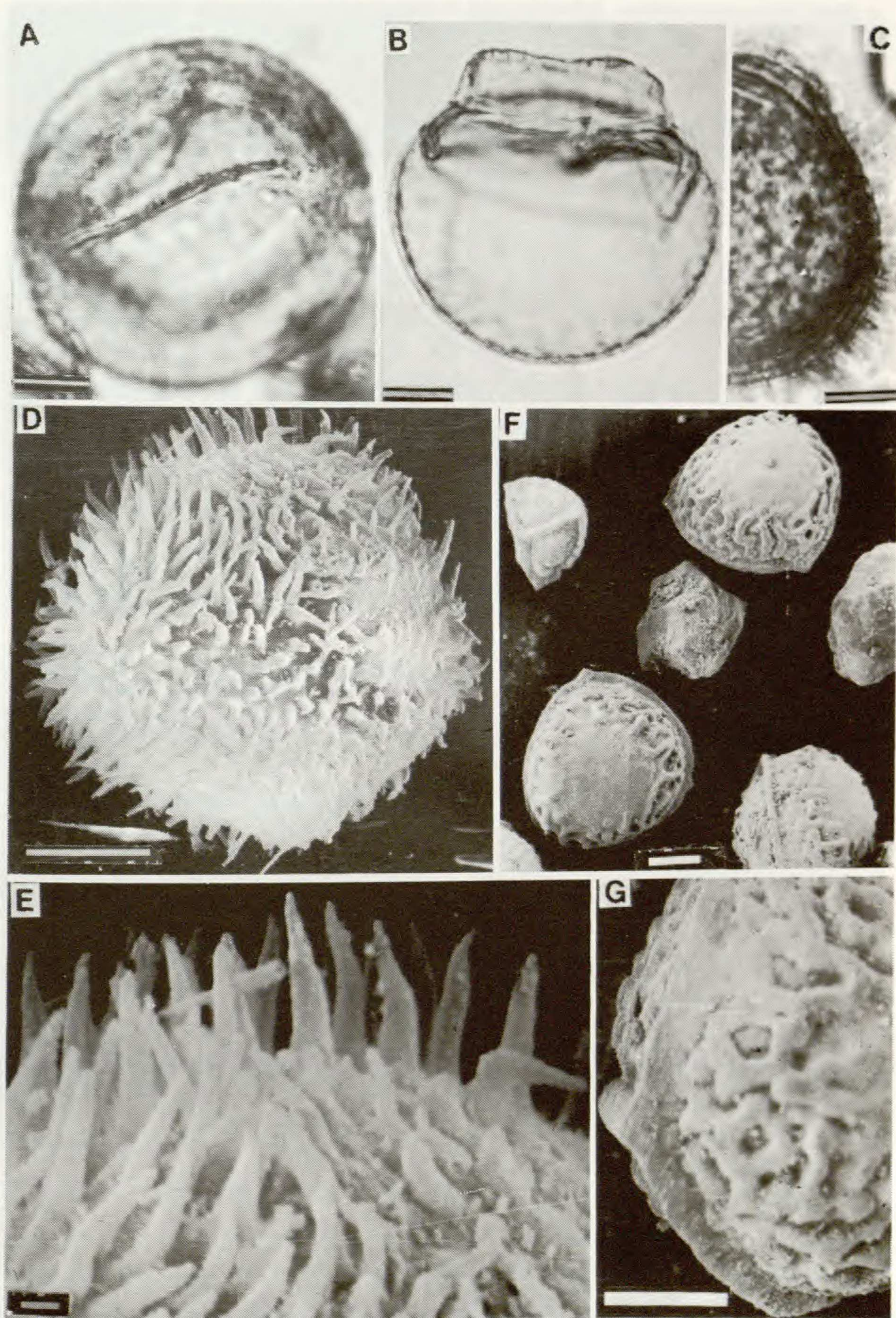


Fig. 4. A-C (LM) and D, E (SEM) photomicrographs of microspores and F, G (SEM) photomicrographs of megaspores of *I. mahadevensis*. A, proximal view; B, lateral view; C, a portion of margin showing spines; D, lateral view; E, a portion in Fig. 4 D further magnified to show the details of spines; F, three large and one small megaspores lying in different angles; G, a portion of large megaspore in Fig. 4 F further magnified to show details of the surface. Bars in A-C = 8 μ m; D = 10 μ m; E = 1 μ m; F, G = 100 μ m.

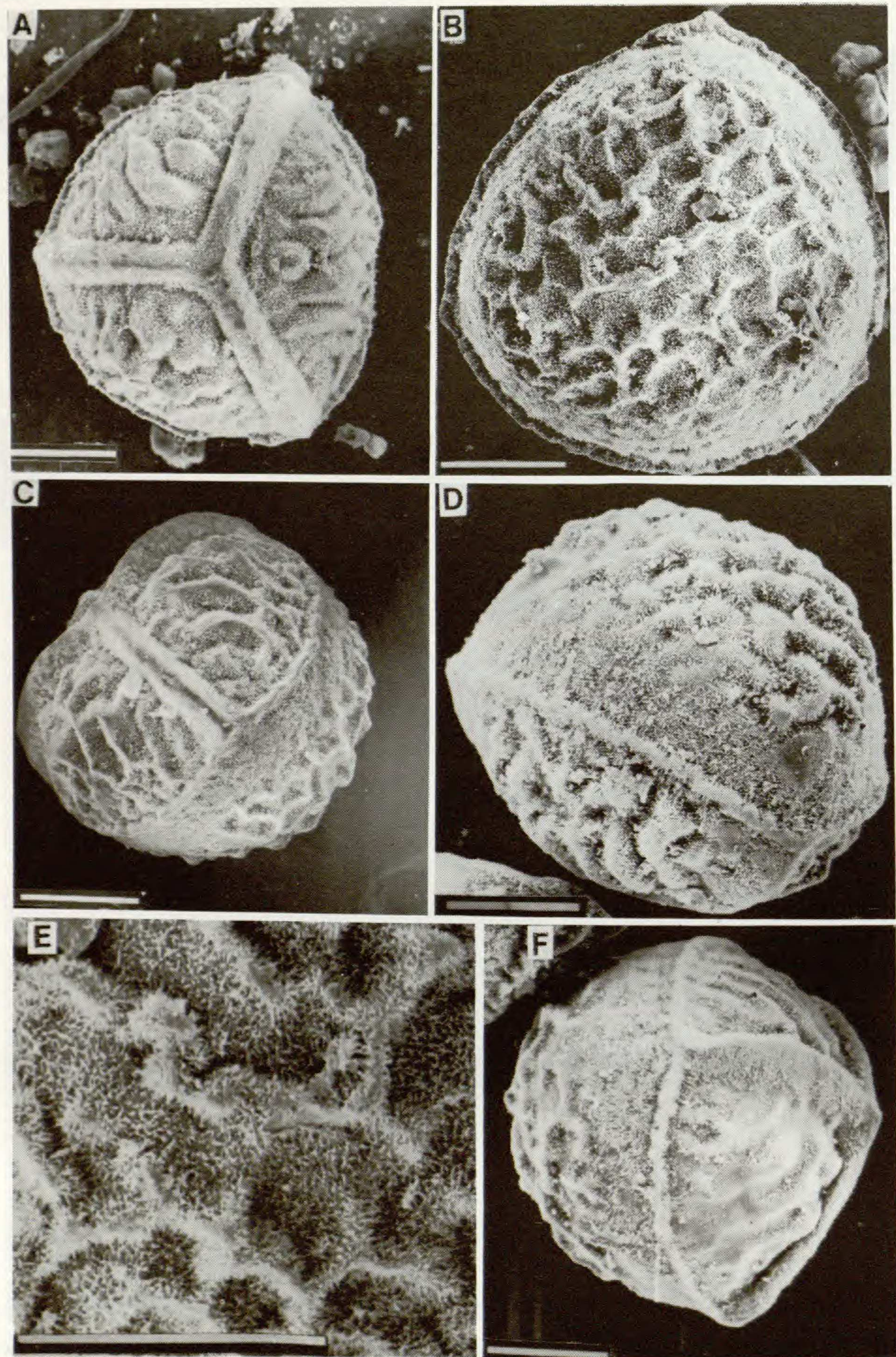


Fig. 5. A-F SEM photomicrographs of megaspores of *I. panchganiensis*. A, proximal view; B, distal view, C, D, F, lateral views; E, a portion of Fig. 5 B further magnified to show infrastructure details of the surface. Bars in A-F = 100 μ m.

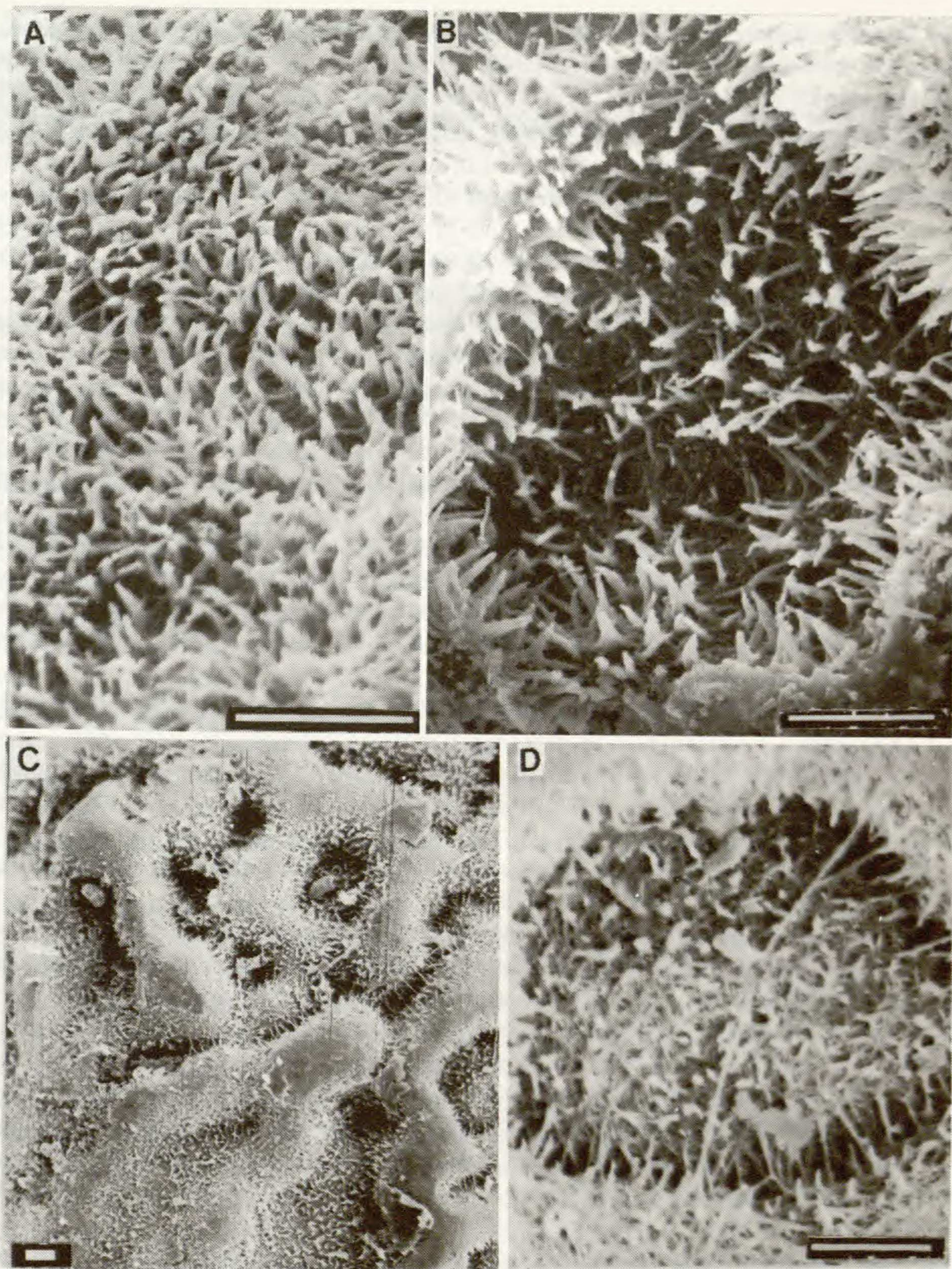


Fig. 6. A, B SEM photomicrographs of portions of megaspores of *I. panchganiensis*, and C, D of *I. mahadevensis* magnified to show infrastructure details of their surfaces. Bars in A-D = 10 μ m.

except for a small ovally-elongated, 1.2 mm broad, and 0.8 mm high window at base; sporangia ovoid, flattened at upper end, 2.5–3.0 mm wide, and 3–4 mm long; megaspores trilete, grey when wet, white when dry, dimorphic, larger ones, pyramidal-globose, 270 μ m–456 μ m (\bar{x} = 364 μ m), spore wall four layered, perispore reticulate distally, lacunae generally complete, separated from one another by muri, anticlinal height of muri greater than thickness of muri (tangential width), girdles without reticulations, proximal face with straight, thin trilete ridges 35 μ m–50 μ m high, interradian contact areas without lacunae, equatorial ridge slightly undulating 10

μm –17 μm high; smaller megaspores 185 μm –305 μm (\bar{x} = 244 μm), somewhat flattened, perisporeal ornamentation similar to that of larger megaspores but indistinct on distal face, interradiat contact areas on proximal face with one or two pustules, in SEM photomicrograph entire surface of perispore is covered by siliceous gel-fibres, sometimes interconnected with one another but usually having broken ends forming an irregular net-like pattern in lacunae; exospore and mesospore minutely granulate, firmly attached to each other, mesospore with numerous surface folds, endospore thin, translucent, smooth, with circular outline; microspores unknown.

Isoetes panchganiensis var. **kemangundiensis** Srivastava, Pant, & Shukla var. nov. (Figs. 5 C, D, F). — TYPE: India, State of Karnataka, Kemangundi, Chikmangalur Distr. leg G. K. Srivastava no. 15031A, 1987 CAL; isotypes: K no. 15031B; and Duthie hb. in Bot. Dept. Allahabad Univ. no. 15031C.

Megaspores areolis incompletis et minute majoris; megaspores majores 322 μm –564 μm (\bar{x} = 408 μm); megaspores minores 209 μm –306 μm (\bar{x} = 250 μm).

Megaspores with incomplete areoles and slightly larger; larger megaspores measure 322 μm –564 μm (\bar{x} = 408 μm) and smaller megaspores measure 209 μm –306 μm (\bar{x} = 250 μm).

Plants of *I. panchganiensis* grow submerged and their luxurious growth often forms a mat in the water of small shallow ditches together with *I. dixitei*. The soil is clay and silty loam, and the pH of water is 5.7.

Two varieties of *I. panchganiensis* sp. nov. are distinguished. The type of the species *I. panchganiensis* var. *panchganiensis* shows megaspores which are slightly smaller and usually show complete areoles. The second variety, *I. panchganiensis* var. *kemangundiensis* var. nov. shows larger megaspores with incomplete areoles. The two varieties are assigned to the same species since they are otherwise identical.

The varietal name “kemangundiensis” is derived from the type locality of the variety “Kemangundi”.

A unique feature of this species is a differentiated girdle on the distal face of megaspores adjacent to the equatorial ridge which is devoid of reticulations. No other Indian species shows this feature.

I. panchganiensis is closest to *I. panchananii* in having almost the same type of reticulate megaspore ornamentation. *I. panchganiensis*, however, can be distinguished from *I. panchananii* by several differing characters. First, the velum of *I. panchganiensis* almost completely covers the sporangium whereas the velum of *I. panchananii* covers about half of the sporangium. Second, the reticulate ornamentation of megaspores of *I. panchganiensis* is confined to the central region of the distal face whereas the reticulate ornamentation covers the entire distal face of the megaspores of *I. panchananii* including the girdle. Third, the megaspores of *I. panchganiensis* are slightly larger than those of *I. panchananii*. Furthermore, mature plants of *I. panchganiensis* are generally smaller than those of *I. panchananii*. In addition the sporangial wall of *I. panchganiensis* does not show thick-walled cells like those present in the sporangial wall of *I. panchananii*. SEM photomicrographs of megaspores of *I. panchganiensis* show relatively thicker siliceous gel-fibres. They do not form connected networks and their broken ends appear as peg-like structures while the siliceous gel-fibres of megaspores of *I. panchananii* form a network over the muri and lumina of the reticulations. *I. panchganiensis* is also comparable to *I. reticulata* and *I. rajasthanensis* in having a complete velum, with only a basal slit. The characteristic smooth girdle of *I. panchganiensis*, however, distinguishes it clearly from them as do the differences in the pattern of siliceous gel-fibres. In *I. panchganiensis* siliceous gel-fibres are often interconnect with one another and form an irregular network while in *I. reticulata* they do not interconnect with one another.

An aberrant plant having a velum almost completely covering the sporangium had been mentioned by Pant & Srivastava (1962) as having been collected from the same locality, Panchgani. Since these authors had only one plant, they failed to recognize it as a new species and assigned it tentatively to *I. panchananii*, but this can now be referred to the present species.

The specific name "panchganiensis" is derived from the type locality of the species "Panchgani."

QUILLWORT FLORA OF INDIA

The present study raises the number of Indian species of *Isoëtes* to thirteen whose distribution is depicted in Fig. 7. An artificial key for the identification of these species is provided at the end of this paper. Indian species of *Isoëtes* can be assigned to different sections of infrageneric (supra specific) classification system in *Isoëtes* which was given by Pfeiffer (1922) and later modified by Fuchs (1962, 1981). Of these, seven species, *I. coromandelina*, *I. sahyadriensis*, *I. dixitei*, *I. indica*, *I. pantii*, *I. bilaspurensis*, and *I. tuberculata* have tuberculate or pustulate megaspores and are therefore assignable to be the section *Palustres* [A. BRAUN, in mss., ex] GRENIER in GRENIER & GODRON (1856), emend. FUCHS (1982) [= sectio *Tuberculatae* PFEIFFER (1922)]. The only species which can be assigned to the section *Isoëtes* [= Sectio *Cristatae* PFEIFFER (1922)] is *I. sampathkumaranii* since Pant & Srivastava (1962) had clearly demonstrated that it showed at some places confluent pustule bases forming small ridges on the distal face of the megaspores (see Pl. 13, figs. 5–8). Although Rao (1944) had mentioned that the megaspores of this species showed "upper segments marked with reticulate branched ridges." The remaining five species, viz., *I. panchananii*, *I. reticulata*, *I. rajasthanensis*, *I. panchganiensis*, and *I. mahadevensis* show reticulations on the distal megaspore faces and are thus attributable to the section *Terrestres* [A. BRAUN in mss., ex.] GRENIER in GRENIER & GODRON (1856), emend. FUCHS (1982) [= Sectio *Reticulatae* PFEIFFER (1922)]. Presently no Indian species is assignable to the sections *Echinatae* Pfeiffer (1922) and *Laeves* Fuchs (1981).

As far as the species of the section *Palustres* are concerned, the proximal as well as the distal faces of megaspores show essentially similar ornamentation, but the megaspores of other Indian species belonging to sections *Isoëtes* and *Terrestres*, show typical sculpturing of the respective sections only on the distal faces of the larger megaspores, the proximal faces of larger as well as smaller megaspores of these species are atypical. In *I. sampathkumaranii* the distal faces of the megaspores show reticulate branched ridges as described by Rao (1944) but their proximal faces bear pustules or small ridges. Similarly distal faces of megaspores of *I. rajasthanensis* show rugulae but their proximal faces have pustules or small rugulae. The megaspores of *I. panchananii* and *I. panchganiensis* show distinct areoles formed by muri on the distal faces but the muri never form areoles on their proximal faces. Earlier workers (Boom, 1980; Duthie, 1929; Hickey, 1986; Proctor, 1949; Williams, 1943) have already mentioned that the proximal and the distal faces of megaspores may show different ornamentation. Hickey (1986) has in particular mentioned that 'it has generally been assumed that the distal spore face represents the "official" character state and it is on the basis of its ornamentation alone that species have been classified.' He further points out that "a species like *I. eshbaughii* could be assigned to either sect. *Isoëtes* or *Palustres* on the basis of distal spore morphology, whereas using the proximal ornamentation it could be included only in sect. *Palustres*." We would, how-

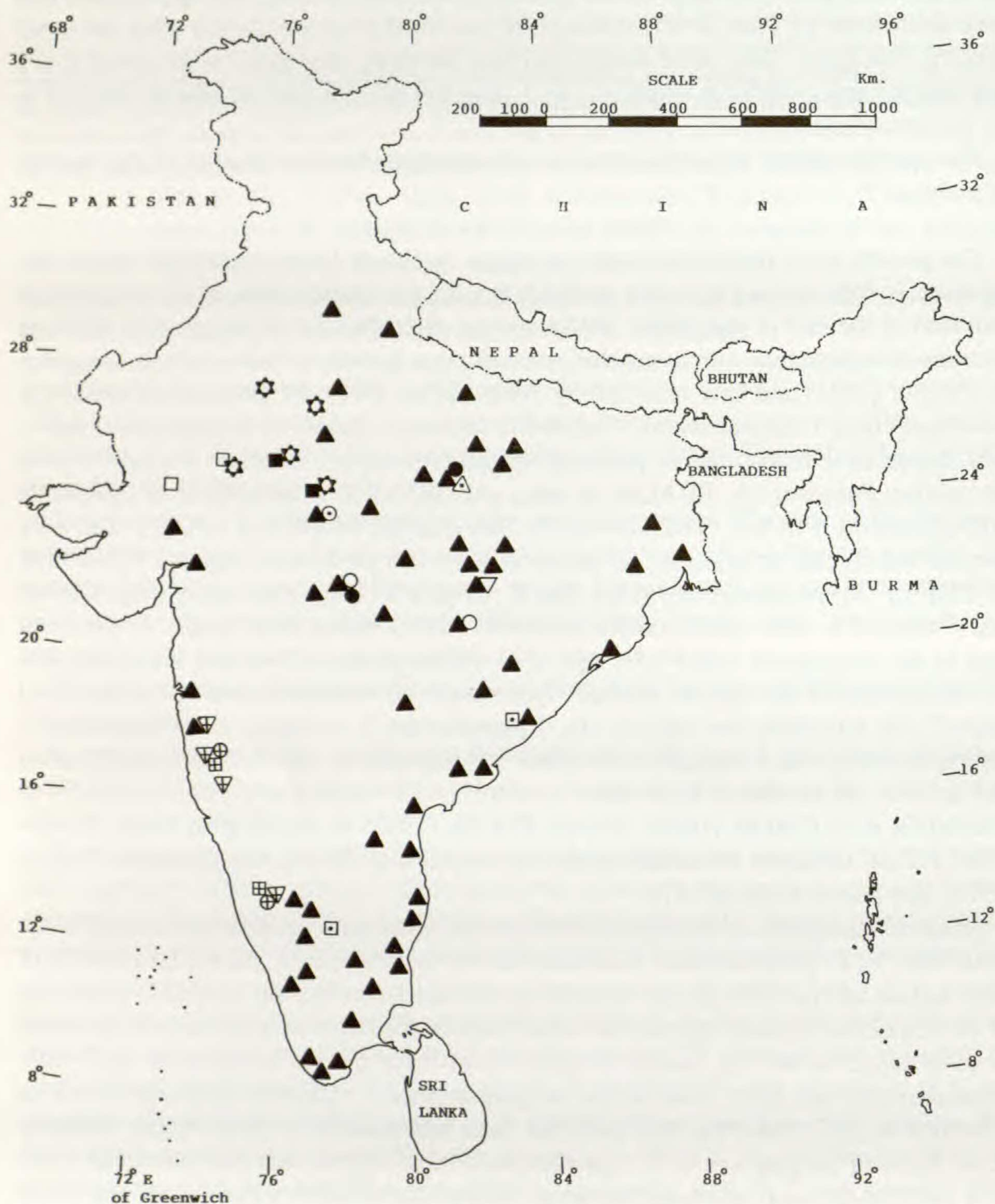


Fig. 7. Map of India depicting the geographical distribution of difference species of *Isoetes*. Open triangle = *I. bilaspurensis*; Closed triangle = *I. coromandelina*; Cross in triangle = *I. dixitei*; Dot in triangle = *I. indica*; Open circle = *I. mahadevensis*; Closed circle = *I. panchananii*; Cross in circle = *I. panchganiensis*; Dot in circle = *I. pantii*; Open square = *I. rajasthanensis*; Closed square = *I. reticulata*; Cross in square = *I. sahyadriensis*; Dot in square = *I. sampathkumaranii*; Star = *I. tuberculata*.

ever, suggest that in classifications based on megaspore morphology it will be better if we consider the ornamentation on both faces instead of single face morphology since it is expected that we would arrive at a more natural classification by taking into account all the available characters. So far as megaspores are concerned, if it becomes necessary we

should be prepared to increase the numbers of sections of *Isoëtes* to accomodate forms with differing proximal-distal face ornamentation of larger megaspores as well as the differing ornamentation of smaller megaspores.

The occurrence of two kinds of megaspores seems to be a general feature of all Indian species of the genus, since this is so not only in almost all previously described species, but also in the two new ones described here. *I. sahyadriensis* may be the only exception, but the account given by Mahabalé (1938) lacks necessary details and the type is not traceable; in spite of several attempts to collect duplicate material, we were unable to find the species in the type locality.

A review of the literature shows that megaspore dimorphism is quite prevalent even in species of *Isoëtes* described from Africa (Braun, 1868; Pfeiffer, 1922; Duthie, 1929; Alston, 1956; Reed & Verdcourt, 1956; Wanntorp, 1970; Hall, 1971) and Australia (Marsden, 1976). Perhaps there is a need to reexamine all species of the genus to confirm the presence or absence of this character.

The factors responsible for the prevalence of dimorphism of megaspores of *Isoëtes* are not definitely known. Irregular meiosis observed in many species, particularly the Indian ones, could, however, be the cause since that has been observed in *I. coromandelina* (Abraham & Ninan, 1958; Verma, 1961) and *I. indica*, *I. panchananii* and *I. pantii* (Pant & Srivastava, 1965; Goswami, 1975). In this connection, Ninan (1958) has observed that "in the megaspore mother cells of *I. coromandelina* there is no chromosome reduction during 'meiosis' and consequently megaspores with the unreduced number of chromosomes are formed" and such observations have also been confirmed in the other three species. However, Marsden (1976a) has suggested that polyploidy and apomixis may be the possible causes of polymorphism of megaspores in *I. muelleri* A. Br. Further work is necessary to establish the factors responsible for dimorphism of spores in different species of the genus.

The altitudinal distribution of the species of *Isoëtes* in India shows that taxa having pustulate or tuberculate megaspores show a wide altitudinal range in their distribution. A species like *I. coromandelina* occurs from the near sea level to fairly high hilly regions (up to 1075 m). Even amongst such species, however, *I. dixitei* and *I. sahyadriensis* are confined to the hills from 1350 m to 1923 m. On the contrary, the reticulate spored species like *I. panchananii*, *I. rajasthanensis*, *I. reticulata*, *I. mahadevensis*, and *I. panchganiensis* are confined only to higher altitudes (from 287 m – 1923 m).

KEY FOR THE IDENTIFICATION OF THE INDIAN REPRESENTATIVES OF *ISOËTES* L.

1. Megaspores: tuberculate or pustulate

[Section *Palustres* (= *Tuberculatae*)]

2. Sporangia described as microsporangia containing mixed small spores (microspores 15–54 µm in diameter) and a few large megaspores about 200 µm in diameter

I. pantii

2. Megasporangia containing only di- or trimorphic megaspores

3. Megaspores tuberculate, tubercles with pointed apices and of almost uniform size

I. indica

3. Megaspores pustulate, pustules with rounded apices

4. Pustules of almost uniform size

5. Velum present covering 2/3 of megasporangia

I. bilaspurensis

5. Velum absent

6. Megaspores dimorphic

I. coromandelina

6. Megaspores trimorphic

I. tuberculata

4. Pustules of distinctly heterogenous size

7. Velum complete having only a slit-like aperture at the base

I. sahyadriensis

7. Velum rudimentary

I. dixitei

1. Megaspores: Reticulate, retate, rugulate

[Section *Terrestres* (= *Reticulatae*)]

8. Anticlinal height of muri almost equal to or less than tangential thickness of muri, velum rudimentary

I. mahadevensis

8. Anticlinal height of muri greater than tangential thickness of muri

9. Velum covering more than 3/4 of the sporangium

10. Reticulations present only on central part of distal face, absent in girdles

I. panchganiensis

10. Reticulations present all over the distal face

11. Megaspores dimorphic

I. reticulata

11. Megaspores trimorphic

I. rajasthanensis

9. Velum covering 1/2 - 3/4 of sporangium

12. Muri generally forming areoles

I. panchananii

12. Muri in the form of very short cristae rarely forming areoles

I. sampathkumaranii

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